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# MILK COOLING ON CALIFORNIA DAIRY FARMS

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## FOREWORD

This bulletin is a contribution of the Division of Agricultural Engineering, and the Committee on Dairy Refrigeration of the California Committee on the Relation of Electricity to Agriculture. It is the fifth of a series planned to report the results of investigations conducted jointly by the Agricultural Experiment Station, College of Agriculture, University of California, and the California Committee on the Relation of Electricity to Agriculture.[1] The committee represents the agricultural and electrical industries in California that are working together for the purpose of making available some reliable information concerning the use of electricity on the farm, and the purpose of cooperating with similar committees in other states.

C. B. Hutchison,
Director, California Agricultural Experiment Station.

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* The personnel of this committee for 1929–30 is:

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# MILK COOLING ON CALIFORNIA DAIRY FARMS

B. D. MOSES[2] AND J. R. TAVERNETTI[3]

## INTRODUCTION

According to the figures of the State Department of Agriculture, in 1928 there were 626,000 dairy cows in California that produced 485,112,970 gallons of milk; of this amount 128,827,209 gallons were used for market milk purposes.

In the production of market milk, state and city laws require the dairyman to use some means of cooling the milk immediately after drawing it from the cow. This requirement has given rise during the past few years to the use of mechanical refrigerating machines for milk cooling on the dairy farm. Because this application is relatively new and because there has been a lack of information regarding this particular use, the California Committee on the Relation of Electricity to Agriculture undertook a study of milk cooling on California dairy farms. The study consisted in obtaining information and conducting observations on farm milk cooling plants in operation in various parts of the state. The data and recommendations in this bulletin are the results of this study.

## PURPOSE OF COOLING MILK

The purpose of cooling milk is to retard increase of bacteria which it may contain, and thus preserve its quality for a longer period of time. Bacteria enter the milk from the udder of the cow, with dirt, dust, insects, and such foreign material, and from unsterilized utensils. Most of the bacteria found in milk increase most rapidly at temperatures between 70 and 100 degrees Fahrenheit. Below 70 degrees the rate of increase of bacteria decreases with the lowering of temperature until the freezing point is reached, where it is practically stopped. Some bacteria, however, continue to develop even at freezing temperatures. Low temperatures do not kill most bacteria but cause them to remain dormant until warmed again, when they resume their activity.

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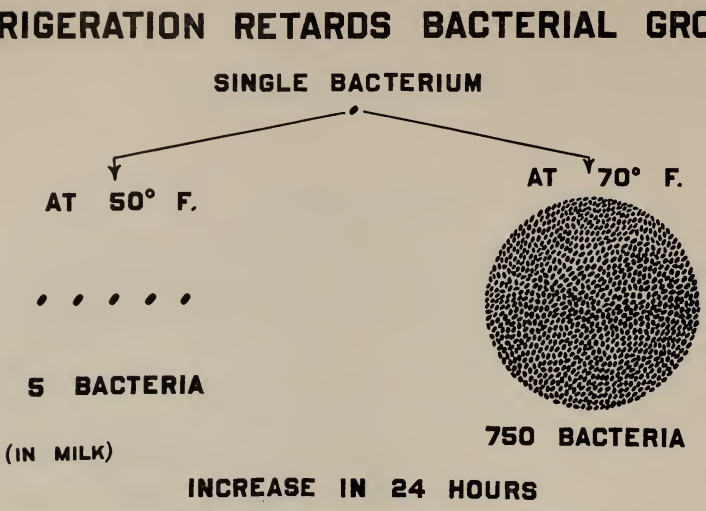



Fig. 1.—The effect of temperature upon bacterial growth.

TABLE 1

THE EFFECT OF TIME AND TEMPERATURE UPON BACTERIAL INCREASE IN MILK[5]

| Temperature of milk, degrees Fahr. | Bacteria at the end of | | | |
|---|---|---|---|---|
| | 24 hours | 48 hours | 96 hours | 168 hours |
| 32 | 30,000 | 27,000 | 24,000 | 19,000 |
| 36 | 38,000 | 56,000 | 4,300,000 | 38,000,000 |
| 42 | 43,000 | 210,000 | 5,760,000 | |
| 50 | 89,000 | 1,940,000 | ..... | ..... |
| 55 | 187,000 | 38,000,000 | ..... | ..... |
| 60 | 900,000 | 168,000,000 | ..... | ..... |
| 68 | 4,000,000 | 25,000,000,000 | ..... | ..... |
| 86 | 14,000,000,000 | ..... | ..... | ..... |
| 94 | 25,000,000,000 | ..... | ..... | ..... |

Each sample contained 30,000 bacteria per cubic centimeter at the start.

Since milk coming from the cow at approximately 100 degrees Fahr. contains bacteria, immediate cooling to a low temperature is essential for preserving the quality. Freezing of milk, however, should be avoided. In order to obtain a low bacteria count, not only is it necessary to cool the milk, but precautions should be taken to prevent the entrance of bacteria during the milking and handling operations.

[4] Adapted from: Bowen, John T. The application of refrigeration to the handling of milk. U. S. Dept. Agr. Bul. 98:1–88. 1914.

[5] Data from: Bowen, John T. The application of refrigeration to the handling of milk. U. S. Dept. Agr. Bul. 98:1–88. 1914.

## DAIRY LAWS

The State of California has established requirements for the cooling of milk to be sold for human consumption, these in many instances are amplified by cities having their own ordinances.

For the purpose of regulation, milk is classified by state law as follows:

- Milk
  - Market
    - Ungraded
    - Graded
  - Manufacturing
  - Unfit for Human Consumption
- Certified
- Guaranteed
  - Raw
  - Pasteurized
- Grade A
  - Raw
  - Pasteurized
- Grade B — Pasteurized

The state requirements for the various grades of market milk are as follows:

"Certified milk shall be cooled to 45° F and shall not contain more than 10,000 bacteria per cubic centimeter when delivered to the consumer.

"Guaranteed raw milk shall be cooled to 50° F immediately after being drawn from the cow and so maintained until delivered to the consumer, when it shall contain not more than 15,000 bacteria per cubic centimeter.

"Guaranteed pasteurized milk shall be cooled to 50° F immediately after being drawn from the cow and so maintained until delivered to the consumer. It shall not contain more than 15,000 bacteria per cubic centimeter before pasteurization and 3,000 after pasteurization.

"Grade 'A' raw milk, when distributed twice a day by the producer, must be cooled to a temperature of 60° F or below, immediately after being drawn from the cow, and so maintained until delivered to the consumer. Grade 'A' raw milk bottled at a distributing plant must be cooled to a temperature of 55° F, or below, immediately after being drawn from the cow and so maintained until delivered to the consumer.

"All Grade 'A' raw milk shall not contain more than 50,000 bacteria per cubic centimeter when distributed to the consumer.

"Grade 'A' pasteurized milk shall be cooled to as low a temperature as practical immediately after being drawn from the cow and so maintained until delivered to the plant. After pasteurization, milk must be cooled to a temperature of 50° F. or below and so maintained until delivered to the consumer. It shall not contain more than

150,000 bacteria per cubic centimeter before pasteurization and 15,000 after pasteurization.''[6]

The main difference between the state and city regulations is in the requirement for cooling Grade A milk for pasteurization. In the production of this grade, the state law does not specify a definite temperature below which the milk must be cooled immediately after coming from the cow. The city regulations, in most cases, however, do state a definite temperature, ranging from 50° to 65° F., below which this grade of milk must be cooled on the farm.

## TYPES OF MILK COOLING AND STORING PLANTS

Two general types of milk cooling and storing plants are in use, the 'wet' and the 'dry.'

The 'wet' type, which is used but little in California, consists of an insulated tank of either brine or water, cooled by a refrigerating machine. In some cases an aerator (milk cooler) and a small pump for circulating the brine or water through the aerator are used. When no aerator is used, the milk, after being drawn from the cow, is placed in either five or ten-gallon cans and submerged in the brine or water, where it is cooled and stored until shipped. When an aerator is used, the milk is first cooled over the aerator by well water, brine, or water from the tank, or by a combination of these, and then placed in cans and stored in the tank until shipped.

This type of plant has the advantages of being (1) low in first cost, (2) easy to build and install, (3) easily accessible for making small quantities of ice, and (4) able to store refrigeration. It has the disadvantages of (1) being limited to storage in cans, (2) being slow in cooling, (3) requiring occasional stirring of the milk unless an aerator is used, (4) being messy, and (5) making it necessary to lift the cans in and out of the tank.

With the 'dry' type of plant, the milk is cooled over an aerator, is placed in either cans or bottles, and then is shipped to the distributing plant or stored in a dry storage box. With this type of plant, two systems of cooling may be used, the brine and the direct expansion. With the brine system, the refrigerating machine cools a tank of brine, and this in turn cools the milk and storage box. With the direct expansion system, the refrigerating machine cools the milk and storage box directly.

[6] Special Publication No. 78, Dairy Laws of California, State Department of Agriculture, Sacramento.

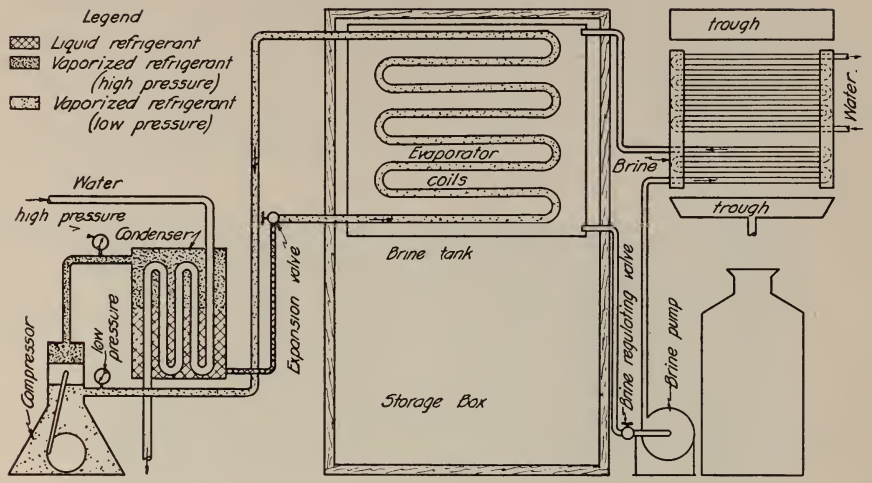



Fig. 2.—Parts of a milk cooling and storing plant using the brine system.

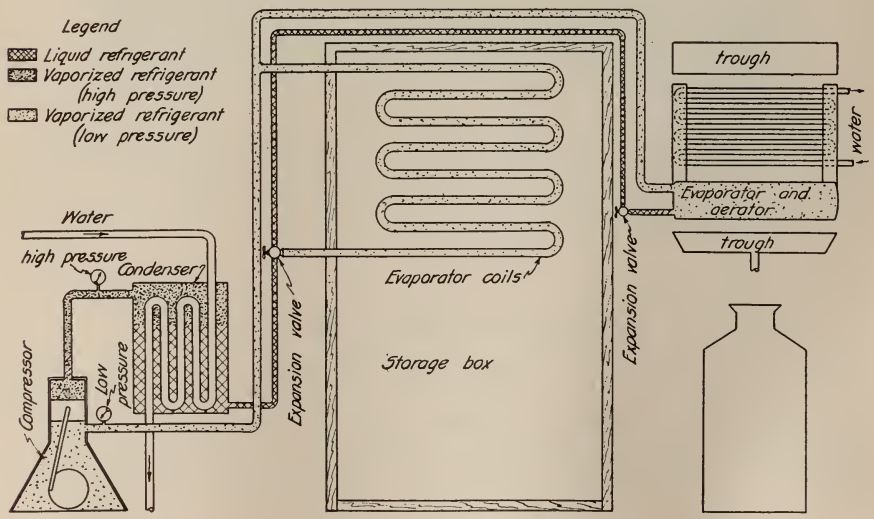



Fig. 3.—Parts of a milk cooling and storing plant using the direct expansion system.

## COMPARISON OF BRINE AND DIRECT EXPANSION SYSTEMS

Advantages of the brine system are:

1. The compressor is smaller.
2. Refrigeration can be stored in the brine tank.
3. A fairly uniform storage box temperature is maintained.

Disadvantages of the brine system are:

1. More equipment is necessary—a brine tank and brine pump and usually a brine pump motor.
2. Three heat transfers are required—milk to brine, brine to refrigerant, and refrigerant to compressor cooling medium.
3. Extra care is necessary for cleanliness.

Advantages of the direct expansion system are:

1. Less equipment is needed.
2. Only two heat transfers are necessary—milk to refrigerant and refrigerant to compressor cooling medium.
3. The system is usually cleaner.
4. The operating cost is lower.

Disadvantages of the direct expansion system are:

1. The compressor is larger.
2. Refrigeration cannot be stored.
3. It is difficult to keep a uniform storage box temperature.
4. The aerator cannot readily be removed for sterilization.
5. The aerator temperature is difficult to control.
6. The danger of freezing milk is greater.

## REFRIGERATING MACHINE

The function of the refrigerating machine is to extract the heat from the milk and storage box and transfer it to some external cooling medium. The refrigerating machine is composed of five parts: namely, compressor, condenser, liquid tank, expansion or float valve, and evaporator. The medium of heat transfer is the refrigerant.

The purpose of the *compressor* is to compress the vaporized refrigerant to a high pressure which raises the temperature and makes it possible to extract the heat taken up in evaporation. There are many different makes and types of compressors on the market, but in all of them the principle of operation is approximately the same.

The purpose of the *condenser* is to condense the vaporized refrigerant to a liquid by extracting the heat taken up in the evaporator. Two different cooling mediums are used, air and water.

The advantages of the water-cooled type are greater efficiency and a smaller motor. The disadvantages are that it requires a constant flow of water when running, it is more complicated, and there is danger of water pipes freezing in cold weather.

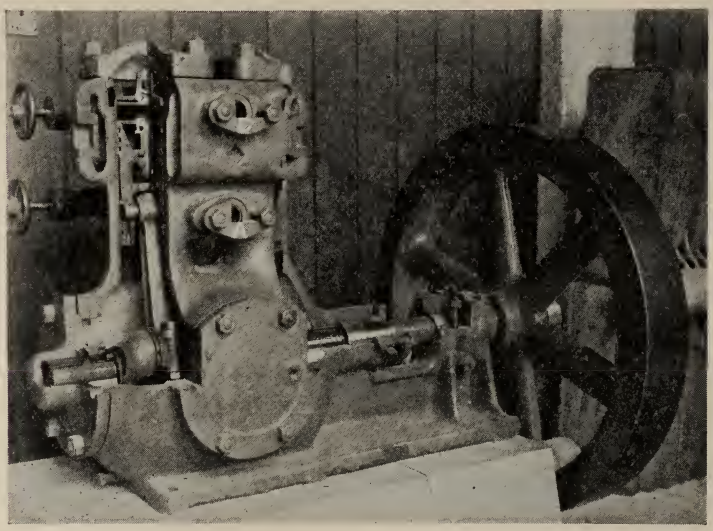


Fig. 4.—Section of a 2-ton ammonia compressor, showing internal mechanism. The gaseous refrigerant enters the compressor through port *A*, is drawn into the cylinder through the valve *B* in the piston head, at the downward stroke of the piston. At the upward stroke of the piston it is compressed, is forced out through valve *C* in the cylinder head, and leaves the compressor through the port *D*.

The advantages of the air-cooled type are that it has simple apparatus, is easier installed, and the place of installation is not limited by water supply. The disadvantages are its lower efficiency and larger motor.

The purpose of the *liquid tank* is to store the liquid refrigerant from the condenser. In some cases the condenser acts as a liquid tank also.

The purpose of the *expansion* or *float valve* is to release the liquid refrigerant from a high pressure to a low pressure, lowering the boiling point and permitting it to evaporate and absorb heat. The expansion valve is used with the 'dry' type of evaporator, the float valve with the 'flooded' type of evaporator. The expansion valve may

be either hand-controlled or automatic, while the float valve is automatic.

The purpose of the *evaporator,* as the name implies, is to evaporate the refrigerant. As soon as the liquid refrigerant is released into the evaporator, its boiling point is lowered to a temperature below that of the substance surrounding the exterior of the evaporator. The refrigerant, in consequence, absorbs the heat from this substance

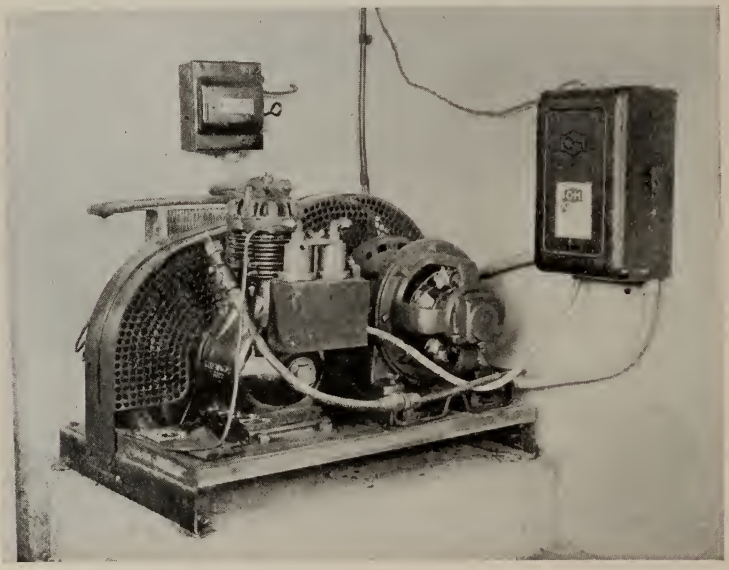


Fig. 5.—An air-cooled sulfur dioxide refrigerating machine used for cooling milk on a 30-cow dairy farm. It is equipped with a 1½-horsepower motor and during the summer operates about 12 hours per day to cool 75 gallons of milk.

and produces the desired refrigeration. As mentioned under expansion valves, there are two types of evaporators, 'dry' and 'flooded.' In the 'dry' type, the refrigerant evaporates almost immediately after entering the evaporator. In the 'flooded' type, the evaporator is partly full of liquid at all times, the float valve being regulated by the quantity of liquid.

The 'dry' system has the advantages of requiring less refrigerant and giving an easier starting load. The 'flooded' system has the advantage that the heat is transferred more rapidly through surfaces in contact with liquids than through surfaces in contact with gases or mixtures of gases and liquids.

## CHARACTERISTICS OF THE MOST COMMON REFRIGERANTS IN USE

*Ammonia.*—Ammonia ($NH_3$) a compound of nitrogen and hydrogen, is a colorless gas with a pungent and offensive odor. It does not support combustion but may form an explosive mixture under high pressure when mixed with oil vapor. It will attack copper and copper alloys if water is present, but has no effect on iron or steel. It is very soluble in water. Under atmospheric pressure liquid ammonia has a boiling point of –28° F, which makes it well adapted for low temperature operations. Its latent heat of vaporization is 565 B.t.u. per pound, which is an advantage in large-capacity machines because of the smaller amount of refrigerant evaporation required to produce a given amount of refrigeration. It is, however, somewhat of a disadvantage in low capacity machines because of the necessary smallness and fine adjustments of the regulating devices. The operating pressures at standard rating, 5° F suction temperature and 86° F condensing temperature, are 19.57 and 154.5 pounds per square inch (gauge), respectively. Leaks are easily located either by the odor or by the 'smoke' test. The 'smoke' test consists of burning a sulfur stick in the vicinity of the leak, causing an apparently dense smoke to form.

*Sulfur Dioxide.*—Sulfur dioxide ($SO_2$) is a compound of sulfur and oxygen, made by burning sulfur. It is a colorless gas with a pungent, suffocating odor. It is non-poisonous and non-inflammable, and does not support combustion. If mixed with water it forms sulfurous acid, which attacks both iron and copper. It is fairly soluble in water. Under atmospheric pressure liquid sulfur dioxide has a boiling point of 14° F. The latent heat of vaporization is 169.4 B.t.u. per pound, a fact which makes the gas adaptable to small refrigerating units. The displacement necessary is about 2.6 times that of an ammonia machine, for equal refrigerating effects. The operating pressures at 5° F suction temperature and 86° F condensing temperature are –2.88 and 51.75 pounds per square inch (gauge), respectively. Leaks may be located by the odor or by the 'smoke' test, ammonia water being applied with a brush.

*Methyl Chloride.*—Methyl chloride ($CH_3CL$) is a compound of carbon, hydrogen, and chlorine, made from hydrochloric acid and methyl alcohol. It is a colorless gas with a sweet odor resembling

chloroform. It is inflammable in concentrations of between 10 and 15 per cent in air, but does not attack copper or iron. It is only slightly soluble in water. Under atmospheric pressure liquid methyl chloride has a boiling point of –10.66° F, which makes it well adapted for fairly low operating temperatures. Its latent heat of vaporization is 178.5 B.t.u. per pound, so that it is well adapted for smaller refrigerating units. The displacement necessary for equal refrigerating effects is 1.9 times that of an ammonia machine. The operating pressures at 5°F suction temperature and 86° F condensing temperature, are 6.19 and 80.83 pounds per square inch (gauge), respectively. Leaks may be located by the odor or by use of an alcohol flame, to which methyl chloride gas imparts a green color.

*Rating of Refrigerating Machines.*—The American Society of Refrigeration Engineers and the American Society of Mechanical Engineers' standard for refrigerating machine ratings is as follows:

"The capacity of any refrigerating machine shall be expressed in terms of 2,000 pounds of ice-melting effect for 24 hours (288,000 B.t.u.) with 5° F saturation temperature in the suction side and 86° F saturation temperature at the discharge side."

This method of rating is used by practically all the manufacturers of ammonia-refrigerating machines; but a large number of the manufacturers of other types have no standard rating. The ice-making capacity of an ice machine is approximately 65 per cent of the rated capacity.

*Ton Refrigeration.*—A ton refrigeration is equivalent to the heat removed by the melting of one ton of ice or the removal of 288,000 B.t.u. The capacity of a machine in tons or pounds of ice does not mean that the machine is capable of making that much ice, but means that it is capable of extracting the same number of B.t.u. as would be taken up in the melting of that quantity of ice. A one-ton refrigerating machine has a capacity sufficient to extract 200 B.t.u. per minute, 12,000 B.t.u. per hour, or 288,000 B.t.u. per 24 hours.

*Horsepower Requirements.*—For water cooled refrigerating machines about two horsepower per ton capacity is required, while air cooled machines require about three horsepower per ton capacity.

## STORAGE BOX

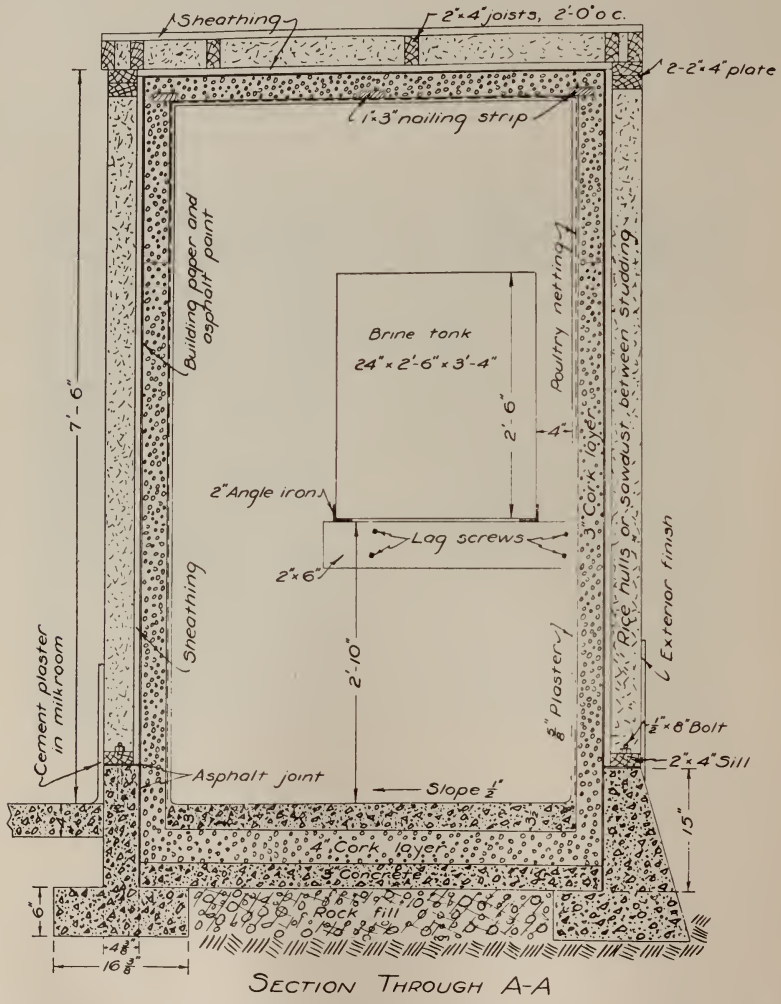
The function of the storage box is to supply low-temperature storage for the milk between the time it is cooled and the time it is taken away from the farm. On dairies where the milk is taken away an hour or so after milking, a storage box is usually not a necessity, but if the milk is held for several hours, it is essential.

There are two general types of dry storage boxes, "the walk-in" and "non-walk-in." They are fundamentally the same in structure

Fig. 6.—Aerator, "walk-in" type storage box and 120-gallon brine tank in use on a 25-cow dairy near Davis. Note that the brine tank is in such a position that cans can be placed underneath, and also is accessible for making ice. This plant is equipped with a ¼-ton refrigerating unit.

but differ in size. The "walk-in" type has a large door and is made so that a man may walk inside. It has the advantages of being more convenient and of providing more storage per unit of floor space because of the possibility of placing the cans or bottle cases one above another. It has the disadvantages of being larger and more expensive to construct and of having a greater wall area. The advantages of the "non-walk-in" type are its smaller size, its cheapness of construction, its smaller wall area, and its ease of being made portable. Its disadvantages are its greater inconveniences and less storage per unit of floor space.

The "walk-in" type is usually built in as part of the milk house, it is used in most of the dairies where more than 100 gallons of milk per day are cooled. The "non-walk-in" type is built as a separate unit from the milk house and is used mostly on dairies where less than 100 gallons of milk per day are cooled.




SECTION THROUGH A-A

Fig. 7*a*.—Detailed construction plans of "walk-in" type storage box shown in figure 6, except that plaster is used as the finish inside instead of tongue-and-groove lumber.

The insulation of a storage box should be the equivalent of 3 to 4 inches of sheet cork. Care should be taken to prevent moisture from coming in contact with the insulation. A good insulation is very essential for an efficient storage box.

The size of the box depends upon the quantity of milk to be stored, the type of box, the location of the brine tank, the method of storing milk, and the type of plant.

The usual practice when milk is stored in bulk is to allow a floor space of about 15 x 15 inches for each 10-gallon can to be stored. When the milk is stored in bottles, a floor space of about 16 x 20 inches is allowed for each stack of bottle cases (12 quarts per case);

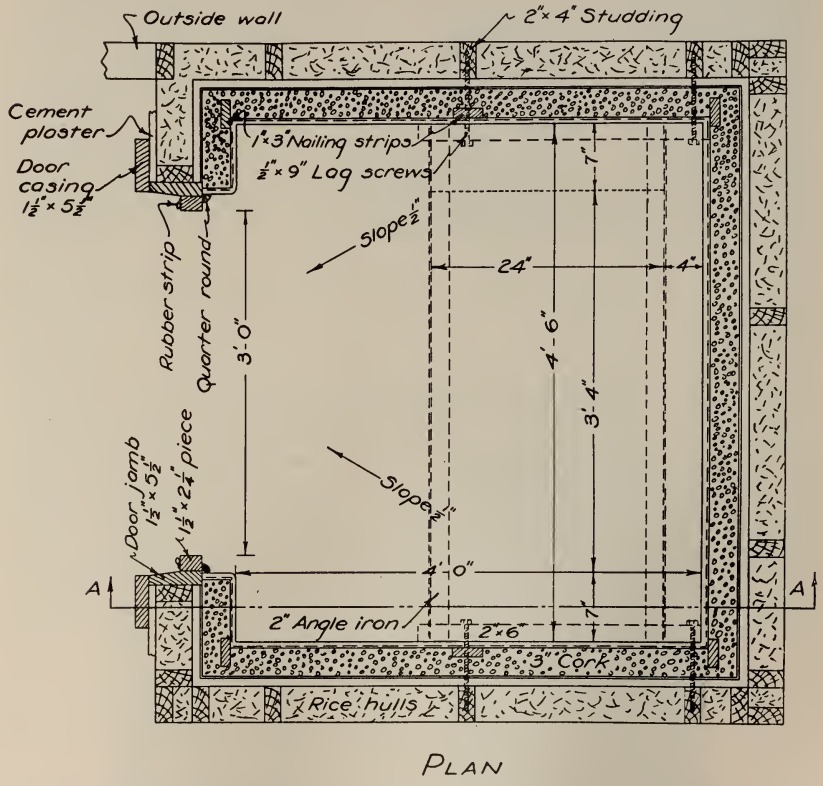



Fig. 7*b*.—Detailed construction plans of "walk-in" type storage box shown in figure 6, except that plaster is used as the finish inside instead of tongue-and-groove lumber.

the height of the stacks will depend upon the height of the box—usually four or five cases with the "walk-in" type box. The quantity of milk to be stored depends upon the time of delivery of the milk, but it is usually desirable to have sufficient storage space for both milkings. In general, the "walk-in" box will have from 50 per cent to 100 per cent more storage capacity than the "non-walk-in" type for the same floor space.

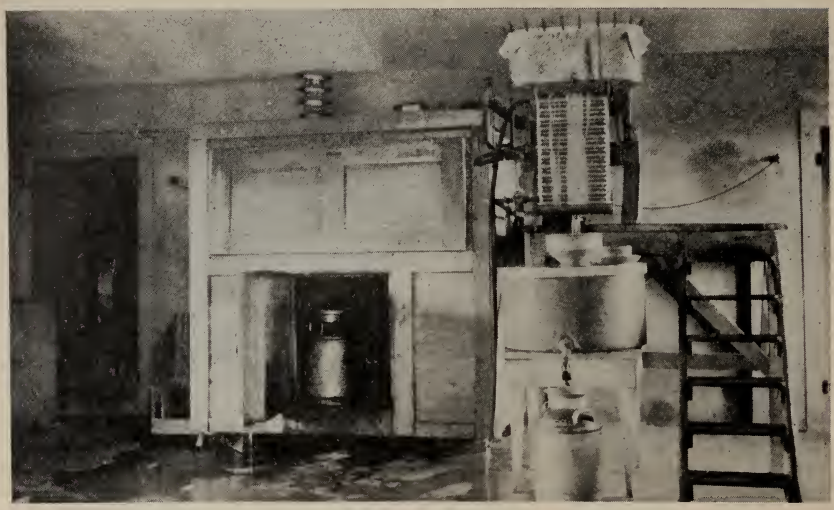


Fig. 8.—A "non-walk-in" type of milk cooling and storing plant in use on a 40-cow dairy. This plant has a 190-gallon brine tank and a 10-can storage space.

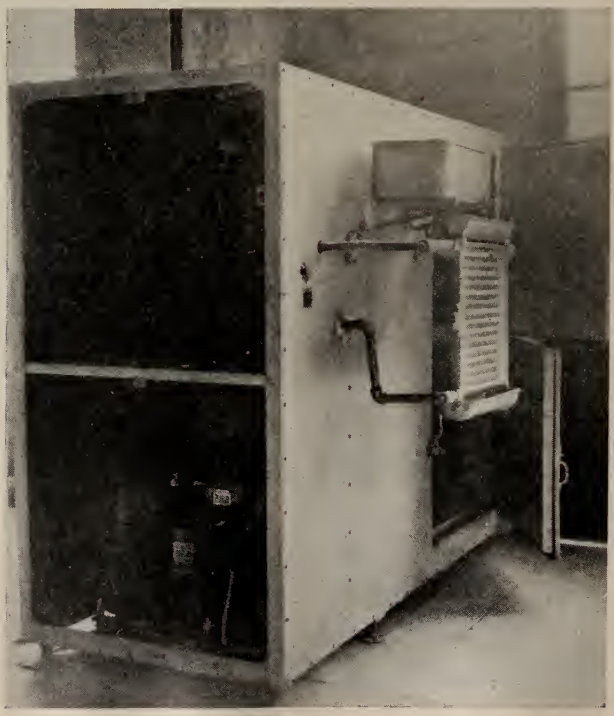


Fig. 9.—A factory-made "non-walk-in" type of milk cooling and storing plant capable of storing eight 10-gallon cans.

The type of plant, whether brine or direct expansion, affects the size of the box in that, with the brine system (on the smaller dairies) the brine tank is usually placed inside the box and cuts down the storage space. With the direct expansion system, coils are placed on the walls of the box, and the storage space is but slightly affected.

### BRINE AND BRINE TANK

The purpose of the brine is to absorb the heat from the milk and storage box and transfer it to the compressor refrigerant. The tank is usually made of galvanized iron and is large enough to hold from 1½ to 2 gallons of brine per gallon of milk cooled per day. The brine

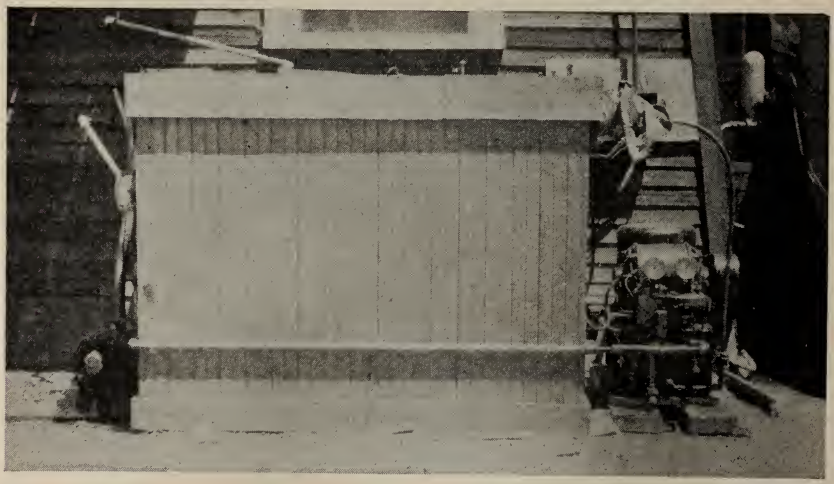


Fig. 10.—Compressor, brine pump and brine tank used for cooling milk on a dairy where no storage is necessary. The brine tank is enclosed in the insulated box, and the brine is pumped through the aerator which is located inside the milk house.

used may be either sodium chloride (common salt) or calcium chloride. The latter has the advantage of a lower freezing temperature with equal concentrations but is more expensive. The concentrations by weight are usually 20 to 25 per cent for common salt and 18 to 20 per cent for calcium chloride, with which it is possible to obtain temperatures of from 0° to 7° F without freezing. The average temperature of the brine is from 20° to 25° F.

The brine tank with the "walk-in" box may be on the floor, at the top, midway between the floor and ceiling, or in a separate box. When it is located on the floor, the floor space for storage is reduced and a larger box is necessary. This location has the advantages, however,

of simplifying installation and providing an easily accessible tank for making ice. When the brine tank is placed at the top, a higher box is required, which increases the area for heat leakage, the construction and installation costs, and the labor of making ice. This location has the advantages of having better air circulation, having more space available for storage, and making possible a neater and more convenient box. When the tank is midway between the ceiling and floor, there are the disadvantages of more difficult installation and decreased accessibility for making ice. The advantages of this location are that all the floor space is available for storage, a smaller box is required, and there is less area for heat loss.

When the tank is placed in a special insulated box by itself, as is usually done when there are 500 or more gallons of brine, an extra box is required which increases the cost and requires more equipment. The advantages of this location are that it is more convenient, is easily accessible for making ice, and makes a neat storage box.

With the "non-walk-in" type of storage box, the brine tank may be placed in the upper portion with storage below, in the center with storage on both sides, or at one side with storage on the other.

## BRINE PUMP

The function of the brine pump is to circulate the brine through the aerator and through the coils in the box when the brine tank is outside of the storage box. The common practice is to use a ½-inch centrifugal pump driven by a ¼-horsepower motor, when less than 200 gallons of milk are cooled a day, and a ¾-inch pump driven by a ¼-horsepower motor for cooling quantities between 200 to 400 gallons per day. In some cases the pump is driven by the belt to the compressor. The pump should be located below the top level of the brine in order to be self-priming.

## AERATOR

The purpose of the aerator is to expose to the air and to quickly cool the milk to a low temperature (about 40° F) immediately after it comes from the cow. The aerator usually consists of a series of horizontal tubes placed one above the other. The cooling is accomplished by allowing the milk to run in a thin sheet over the outside of the tubes, while the cooling medium runs through the inside. The cooling medium enters the aerator through the bottom tube and leaves through

the top tube. When plenty of water is available, the aerator is usually made in two sections, the milk being cooled by water over the upper portion and by brine or refrigerant on the lower portion.

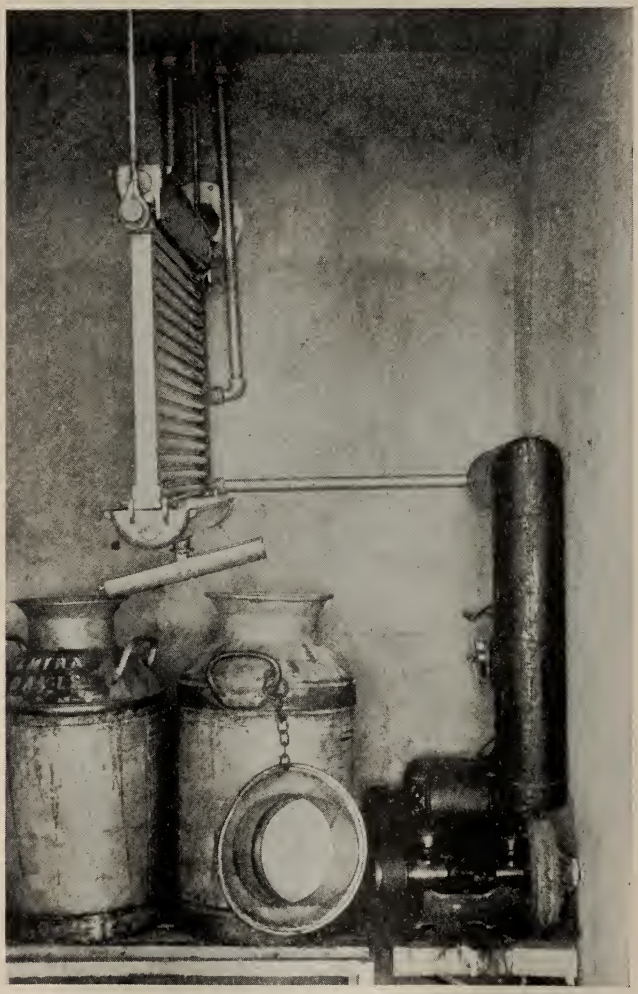


Fig. 11.—Aerator, brine pump and non-spill can filler used on a 30-cow dairy. The aerator is of the two-way type, the milk being cooled by water to within 5° F of the water temperature on the upper half and by brine to about 40° F on the lower half. The can tipper is operated by a float, which is lifted when the milk rises and tips the trough into the other can.

Usually when direct expansion is used the lower portion consists of only one large tube about eight inches in diameter.

Care should be taken to see that the milk runs in a thin sheet over the aerator and not in streaks. This can be accomplished by collecting

the first milk passing over the cooler in a sterile milk bottle or dipper, and pouring it rapidly over the top pipes of the cooler. This wets the entire surface of the cooler with milk, and permits the remainder of the milk to spread more uniformly over the surface.

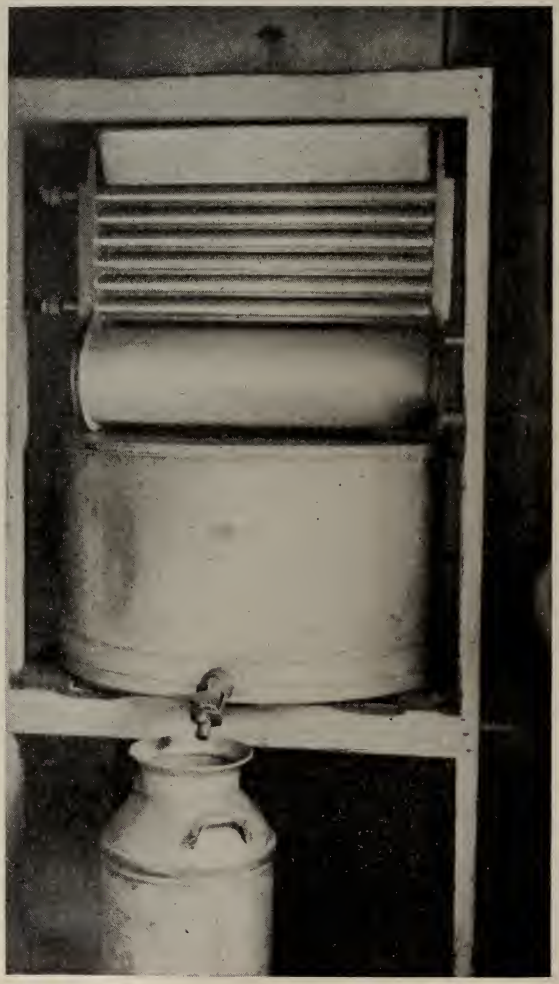


Fig. 12.—Direct expansion type aerator and vats used for cooling milk on a 75-cow dairy. Note the large drum in which the refrigerant is evaporated and on which the milk is cooled to the desired temperature after being precooled by the water portion above.

A rate of flow through the aerator of one gallon of water per minute to each ten gallons of milk per hour will cool the milk to within about 5 degrees of the original temperature of the water. The aerator should be approximately six inches in horizontal length for each ten gallons of milk to be cooled per hour.

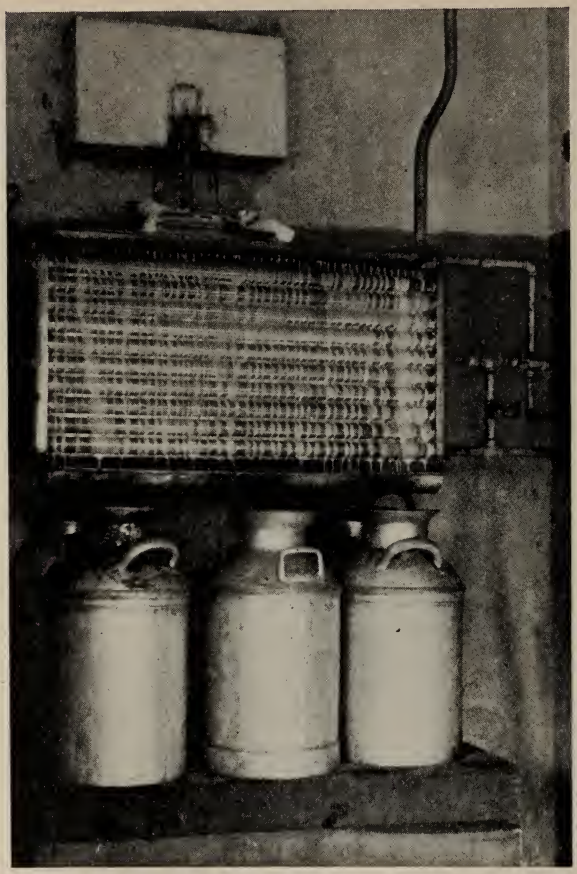


Fig. 13.—Aerator and special trough for filling six cans at a time. This eliminates the necessity for a large vat to catch the milk. Note that the milk is running in streaks and that only a portion of the aerator surface is in use.

## TABULATED RESULTS OF INVESTIGATIONS

Investigational work on the use of ice machines for cooling milk on the dairy farm was carried on during 1928 and 1929.

A survey was conducted during the first part of 1928, in the vicinities of Davis, Sacramento, Stockton, Tracy, Modesto, Turlock, Fresno, Chino, and Ontario. Seventy-three dairies were visited, and data were obtained either by personal observations or by questioning the dairymen. All of the dairies visited were selling market milk, either bottled or in bulk. A summary of the data obtained is given in tables 2, 3, and 4.

## TABLE 2

DESCRIPTIVE DATA OF DAIRY COOLING PLANTS INCLUDED IN SURVEY, GIVING NUMBER OF PLANTS IN EACH DISTRICT HAVING THE ITEMS LISTED

| Item | Davis and Sacramento | Stockton and Tracy | Modesto and Turlock | Fresno | Chino and Ontario | Total number covered by survey |
|---|---|---|---|---|---|---|
| Machines visited | 28 | 14 | 8 | 7 | 16 | 73 |
| Different makes | 8 | 7 | 4 | 2 | 5 | 16 |
| Sulfur dioxide machines | 8 | 4 | 5 | 5 | 7 | 29 |
| Ammonia machines | 19 | 10 | 3 | 2 | 4 | 38 |
| Methyl chloride machines | 1 | 0 | 0 | 0 | 5 | 6 |
| Machines cooled by air | 6 | 0 | 1 | 1 | 2 | 10 |
| Machines cooled by water | 22 | 14 | 7 | 6 | 14 | 63 |
| Direct expansion systems | 7 | 5 | 1 | 0 | 0 | 13 |
| Brine systems | 21 | 9 | 7 | 7 | 16 | 60 |
| Home-made storage boxes | 26 | 14 | 6 | 3 | 4 | 53 |
| Ready-made storage boxes | 2 | 0 | 1 | 0 | 5 | 8 |
| Without storage boxes | 0 | 0 | 1 | 4 | 7 | 12 |
| Sheet cork insulation | 11 | 3 | 3 | 0 | 11 | 28 |
| Granulated cork insulation | 8 | 10 | 1 | 0 | 0 | 19 |
| Sawdust insulation | 3 | 1 | 1 | 3 | 1 | 9 |
| Rice hull insulation | 6 | 0 | 0 | 0 | 0 | 6 |
| Having brine tank inside storage box | 18 | 6 | 7 | 3 | 7 | 41 |
| Having brine tank in special box | 3 | 3 | 0 | 4 | 9 | 19 |
| Having special brine tank for making ice | 0 | 2 | 0 | 1 | 0 | 3 |
| Having calcium chloride brine | 9 | 4 | 4 | 5 | 9 | 31 |
| Having common salt brine | 12 | 5 | 3 | 1 | 6 | 27 |
| Bottling their own milk | 4 | 5 | 3 | 3 | 0 | 15 |
| Delivering twice a day | 2 | 1 | 2 | 4 | 16 | 25 |
| Delivering once a day | 26 | 13 | 6 | 3 | 0 | 48 |
| Precooling with water | 27 | 13 | 8 | 6 | 14 | 68 |
| Making ice for own use | 8 | 4 | 1 | 1 | 4 | 18 |
| With compartment for storing food | 5 | 2 | 0 | 0 | 0 | 7 |
| That have had repairs | 5 | 4 | 0 | 1 | 4 | 14 |
| That are not satisfactory | 1 | 1 | 0 | 2 | 0 | 4 |

## TABLE 3

MAXIMUM, MINIMUM, AND AVERAGE SPECIFICATIONS OF DAIRY COOLING PLANTS COVERED IN SURVEY, ARRANGED ACCORDING TO REFRIGERANT

| | Ammonia* | | | Sulfur dioxide and methyl chloride† | | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Av. | Max. | Min. | Av. |
| Number of cows per dairy | 370 | 15 | 85 | 100 | 16 | 41 |
| Time machine has been in use | 6 yrs. | 2 mo. | 2.4 yrs. | 2 yrs. | 1 wk. | .7 yr. |
| Rated capacity of machine in tons of ice | 4.0 | .25 | 1.6 | .5 | .16 | .35 |
| Horse-power of the compressor motor | 7.5 | .75 | 3.15 | 1.5 | .33 | .80 |
| Size of aerator | 60″ x 36″ | 24″ x 18″ | 35″ x 20″ | 30″ x 25″ | 18″ x 18″ | 25″ x 21″ |
| Capacity of brine tank—gallons | 3000 | 150 | 625 | 400 | 40 | 208 |
| Size of storage box in cubic feet | 1470 | 144 | 450 | 500 | 20 | 160 |
| Temperature of storage box—deg. Fahr. | 50 | 30 | 40 | 58 | 30 | 43 |
| Temperature to which milk is cooled—degrees Fahr. | 50 | 35 | 39 | 50 | 35 | 42 |
| Initial cost of complete plant | $3500 | $325 | $1630 | $1450 | $400 | $930 |

* Thirty-nine machines visited.

† Thirty-four machines visited.

TABLE 4

Summary of Survey Data on Dairy Refrigeration Plants Showing Unit Performance

| | Ammonia | | | Sulfur dioxide and methyl chloride | | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Av. | Max. | Min. | Av. |
| Cubic feet of storage per gallon of milk | 13.0 | .58 | 3.2 | 11.9 | .29 | 2.3 |
| Hours per day to cool milk | 10.0 | 1.0 | 5.4 | 9 | 2 | 4.9 |
| Gallons of milk cooled per day | 1100 | 45 | 235 | 360 | 42 | 124 |
| Gallons of milk cooled per hour | 110 | 15 | 43 | 51 | 11 | 28 |
| Gallons of milk cooled per day per ton capacity | 900 | 33 | 177 | 1440 | 84 | 383 |
| Gallons of brine per gallon of milk per milking | 14.0 | 1.7 | 5.6 | 19.0 | 1.1 | 5.5 |
| Initial cost of plant per 10 gallons of milk cooled per day | $350 | $28 | $104 | $190 | $20 | $85 |
| Initial cost of plant per cow | $80 | $7 | $26 | $59 | $7 | $26.50 |

During the survey, from one to five representative plants were selected in each of the vicinities, and a watt-hour meter was installed on the compressor motor and in some cases also on the brine pump motor. These meters were read at definite intervals of time, and the power consumption was obtained for a period of one year. The results of these tests appear in table 5 and figure 14.

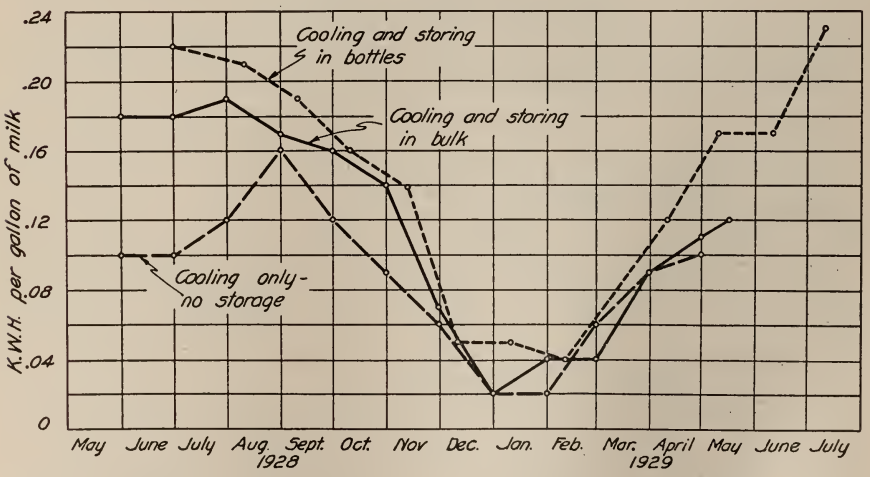



Fig. 14.—Power consumption on three dairies handling the milk differently, but using the brine system.

Six plants were selected in the vicinity of Davis and Sacramento upon which observations of operating characteristics were conducted for one week during each of the four seasons of the year. All of these dairies were cooling and storing their milk in bulk. To determine the

TABLE 5

POWER CONSUMPTION OBSERVATIONS ARRANGED ACCORDING TO THE TYPE OF COOLING SYSTEM AND METHOD OF HANDLING MILK

| Dairy | Number of days on observation | Approximate number of cows milked | Total gallons of milk cooled | Total kilowatt-hours used* | Kilowatt-hours per gallon of milk |
|---|---|---|---|---|---|
| | COOLING AND STORING IN BULK—BRINE SYSTEM | | | | |
| A | 377 | 50 | 42406 | 10220 | .24 |
| B | 367 | 30 | 25608 | 3598 | .14 |
| C | 253 | 75 | 46410 | 4276 | .09 |
| D | 372 | 20 | 25195 | 2731 | .11 |
| E | 377 | 30 | 25150 | 2695 | .11 |
| F | 275 | 65 | 39900 | 3630 | .09 |
| G | 325 | 55 | 40042 | 3486 | .09 |
| H | 370 | 20 | 21541 | 2412 | .11 |
| | | | | Average | .12 |
| | COOLING AND STORING IN BOTTLES—BRINE SYSTEM | | | | |
| I | 377 | 22 | 22620 | 3537 | .16 |
| J | 363 | 25 | 29240 | 6059 | .21 |
| K | 376 | 25 | 18604 | 3979 | .22 |
| L | 243 | 25 | 13250 | 1608 | .12 |
| M | 362 | 35 | 29340 | 4095 | .14 |
| | | | | Average | .17 |
| | COOLING ONLY; NO STORAGE—BRINE SYSTEM | | | | |
| N | 351 | 30 | 37257 | 3048 | .08 |
| O | 288 | 100 | 63863 | 7266 | .11 |
| P | 361 | 20 | 24743 | 1665 | .07 |
| | | | | Average | .09 |
| | COOLING AND STORING—DIRECT EXPANSION SYSTEM | | | | |
| Q | 370 | 75 | 70050 | 2618 | .04 |
| R | 309 | 90 | 90802 | 4642 | .05 |
| | COOLING ONLY—DIRECT EXPANSION SYSTEM | | | | |
| S | 266 | 60 | 36480 | 1964 | .05 |

* Includes power used by both compressor and brine pump motors.

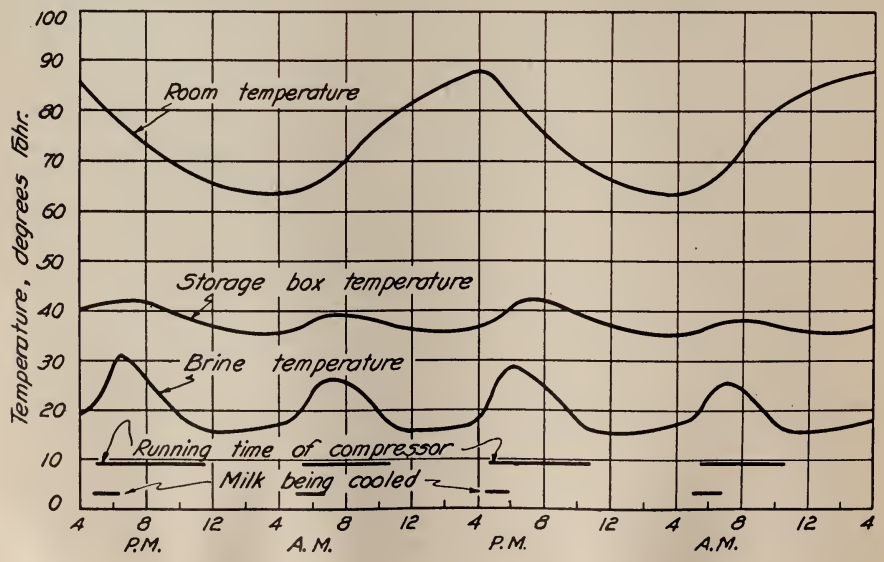



Fig. 15.—Characteristics of a milk plant when cooling 71 gallons of milk per day with a 750-pound ice machine. Taken from summer observation conducted on dairy No. 3.

characteristics on dairies where the milk was cooled and not stored or where it was cooled and stored in bottles, a one-week summer test was conducted on three other dairies. The results of these tests appear in tables 6 to 12 inclusive, and in figure 15.

TABLE 6

Operating Characteristics on Dairy No. 1

Milk cooling plant installed May, 1928.
Ice-melting effect per 24 hours of ice machine: 500 pounds.
Condenser cooling medium: air.
Refrigerant: methyl chloride.
Horsepower of motor: ¾ horsepower.
Type of storage box: "walk-in," made on farm.
Inside dimensions of storage box: 4′ × 4′ × 7′.
Insulation of storage box: 3-inch sheet cork and 4 inches rice hulls.
Gallons of brine: 120.
Kind of brine: calcium chloride.
Location of brine tank: suspended 3′ from floor inside box.
Size and type of brine pump: ½ inch centrifugal.
Horsepower of brine pump motor: ¼ horsepower.
Size and type of aerator: 18″ × 18″ two-way.
Cost of complete plant: $800.

*Remarks:* Ice machine is automatically controlled. One man did all the milking with a two-unit milking machine. Evening's milk was stored overnight and both milkings were hauled by truck a distance of four miles to the distributing plant in the morning.

| | Aug., 1928 | Oct., 1928 | Jan., 1929 | April, 1929 | Average of all tests* |
|---|---|---|---|---|---|
| Number of cows milked | 16 | 15 | 23 | 23 | 19 |
| Gallons of milk cooled per day | 54 | 64 | 90 | 85 | 73 |
| Gallons of milk stored per day | 28 | 34 | 45 | 44 | 38 |
| Hours compressor was run per day | 10.3 | 10.2 | 8.8 | 7.8 | 9.3 |
| Kw.-hr. used by compressor motor | 9.4 | 9.1 | 7.8 | 7.4 | 8.4 |
| Kw.-hr. used by brine pump motor | .8 | .9 | 1.0 | 1.1 | .95 |
| Total kw.-hr. used | 10.2 | 10.0 | 8.8 | 8.5 | 9.4 |
| Average brine temperature, degrees Fahr. | 18 | 12 | 8 | 14 | 13 |
| Degrees rise in brine temperature during cooling, degrees Fahr. | 8 | 8 | 7 | 7 | 7.5 |
| Average storage box temperature, degrees Fahr. | 32 | 28 | 26 | 30 | 29 |
| Average milk room temperature, degrees Fahr. | 73 | 69 | 51 | 61 | 64 |
| Milk temperature before cooling, degrees Fahr. | 95 | 93 | 91 | 95 | 93 |
| Milk temperature after water cooled, degrees Fahr. | 74 | 68 | 64 | 69 | 69 |
| Milk temperature after brine cooled, degrees Fahr. | 37 | 37 | 37 | 40 | 38 |
| Rate of flow of cooling water, g.p.m. | 1.6 | 2.2 | 2.5 | 1.3 | 1.9 |
| Rate of flow of milk over aerator, g.p.h. | 25 | 29 | 27 | 25 | 27 |
| Temperature of cooling water, degrees Fahr. | 69 | 63 | 59 | 62 | 63 |

* Nearest whole number.

## TABLE 7

### OPERATING CHARACTERISTICS ON DAIRY NO. 2

Milk cooling plant installed May, 1927.
Ice-melting effect per 24 hours of ice machine: 500 pounds.
Condenser cooling medium: water.
Refrigerant: sulfur dioxide.
Horsepower of motor: ½ horsepower.
Type storage box: "non-walk-in," factory made.
Inside dimensions of storage box: 3′ × 5′ × 5′.
Insulation of storage box: 4-inch sheet cork.
Gallons of brine: 190.
Kind of brine: calcium chloride.
Location of brine tank: upper portion of storage box.
Size and type of brine pump: ¾ inch centrifugal.
Horsepower of brine pump motor: ¼ horsepower.
Size and type of aerator: two-way 14" wide 24" long.
Cost of complete plant: $1150.

*Remarks:* The ice machine is automatically operated. The evening's milk is stored and both milkings are shipped by truck in the morning a distance of 27 miles to the distributing plant. During the summer test two men were milking by hand and during the other three tests one man did all the milking with a two-unit milking machine.

| | Aug., 1928 | Oct., 1928 | Jan., 1929 | April, 1929 | Average of all tests* |
|---|---|---|---|---|---|
| Number of cows milked | 40 | 40 | 23 | 29 | 33 |
| Gallons of milk cooled per day | 84 | 79 | 43 | 75 | 70 |
| Gallons of milk stored per day | 42 | 39 | 22 | 43 | 36 |
| Hours compressor was run per day | 13.4 | 12.2 | 5.8 | 15.3 | 11.7 |
| Kw.-hr. used by compressor motor per day | 7.6 | 6.5 | 3.4 | 7.8 | 6.3 |
| Kw.-hr. used by brine pump per day | 1.4 | 1.9 | .9 | 1.6 | 1.5 |
| Total kw.-hr. used per day | 9.0 | 8.4 | 4.3 | 9.4 | 7.8 |
| Average brine temperature, degrees Fahr. | 30 | 33 | 30 | 25 | 30 |
| Rise in brine temperature during cooling, degrees Fahr. | 10 | 6 | 5 | 8 | 7 |
| Average storage box temperature, degrees Fahr. | 45 | 43 | 40 | 40 | 42 |
| Average milk room temperature, degrees Fahr. | 79 | 69 | 56 | 65 | 67 |
| Milk temperature before cooling, degrees Fahr. | 94 | 91 | 86 | 89 | 90 |
| Milk temperature after water cooled, degrees Fahr. | 75 | 72 | 71 | 73 | 73 |
| Milk temperature after brine cooled, degrees Fahr. | 44 | 43 | 50 | 51 | 47 |
| Rate of flow of cooling water, g.p.m. | 2.7 | 3.0 | 6.0 | 5.8 | 4.4 |
| Rate of flow of milk over aerator, g.p.h. | 22 | 14 | 18 | 32 | 22 |
| Temperature of cooling water, degrees Fahr. | 68 | 66 | 64 | 60 | 65 |

* Nearest whole number.

## TABLE 8

### Operating Characteristics on Dairy No. 3

Milk cooling plant installed April, 1928.
Ice-melting effect per 24 hours of ice machine: 750 pounds.
Condenser cooling medium: air.
Refrigerant: sulfur dioxide.
Horsepower of motor: 1½ horsepower.
Type of storage box: "walk-in," made on the farm.
Inside dimensions of storage box: 6′ × 6′ × 7′.
Insulation of storage box: 3-inch sheet cork.
Gallons of brine: 150.
Kind of brine: calcium chloride.
Location of brine tank: suspended 3 feet from floor inside box.
Size and type of brine pump: ¾ inch centrifugal.
Horsepower of brine pump motor: ¼ horsepower.
Size and type of aerator: 30″ wide, 18″ deep, two-way.
Cost of complete plant: $1100.

*Remarks:* The ice machine is automatically controlled. A space 2′ × 6′ × 7′ in the storage box was partitioned off for storing food stuffs. One man did all the milking with a two-unit milking machine. The morning's milk was stored and both milkings were shipped a distance of 60 miles by truck in the evening.

| | July, 1928 | Oct., 1928 | Jan., 1929 | April, 1929 | Average of all tests* |
|---|---|---|---|---|---|
| Number of cows milked | 30 | 30 | 30 | 30 | 30 |
| Gallons of milk cooled per day | 71 | 73 | 64 | 74 | 71 |
| Gallons of milk stored per day | 37 | 38 | 35 | 41 | 38 |
| Hours compressor was run per day | 11.9 | 9.1 | 3.7 | 7.6 | 8.1 |
| Kw.-hr. used by compressor motor per day | 13.6 | 10.2 | 4.1 | 8.5 | 9.1 |
| Kw.-hr. used by brine pump motor per day | .7 | .6 | .6 | .5 | .6 |
| Total kw.-hr. used per day | 14.3 | 10.8 | 4.7 | 9.0 | 9.7 |
| Average brine temperature, degrees Fahr. | 20 | 23 | 25 | 21 | 22 |
| Degrees rise in brine during cooling, degrees Fahr. | 9 | 6 | 1 | 4 | 5 |
| Average storage box temperature, degrees Fahr. | 37 | 36 | 30 | 35 | 35 |
| Average milk room temperature, degrees Fahr. | 75 | 67 | 45 | 59 | 62 |
| Milk temperature before cooling, degrees Fahr. | 95 | 94 | 90 | 94 | 93 |
| Milk temperature after water cooled, degrees Fahr. | 79 | 72 | 55 | 68 | 69 |
| Milk temperature after brine cooled, degrees Fahr. | 39 | 38 | 38 | 38 | 38 |
| Rate of flow of cooling water, g.p.m. | 1.7 | 2.0 | 2.5 | 2.5 | 2.2 |
| Rate of flow of milk over aerator, g.p.h. | 25 | 26 | 26 | 28 | 26 |
| Temperature of cooling water, degrees Fahr. | 75 | 66 | 50 | 62 | 63 |

* Nearest whole number.

## TABLE 9

### OPERATING CHARACTERISTICS ON DAIRY NO. 4

Milk cooling plant installed March, 1928.
Ice-melting effect per 24 hours of ice machine: 750 pounds.
Condenser cooling medium: air.
Refrigerant: sulfur dioxide.
Horsepower of motor: 1½ horsepower.
Type of storage box: "walk-in," made on farm.
Inside dimensions of storage box: 6′ × 6′ × 7′.
Insulation of storage box: 6 inches of rice hulls.
Gallons of brine: 200.
Kind of brine: common salt.
Location of brine tank: on floor at one end of the storage box.
Size and type of brine pump: ¾ inch centrifugal.
Horsepower of brine pump motor: ¼ horsepower.
Size and type of aerator: 24″ wide, 15″ deep, two-way.
Cost of complete plant: $1200.

*Remarks:* Ice machine is automatically operated. During the summer and fall tests, three men did the milking by hand. During the winter and spring tests, two men did the milking by hand. The evening's milk was stored over night and both milkings were hauled to the distributing plant. During the year new brushes were put on the compressor motor, new valves put in the compressor, and a new expansion valve installed.

| | Aug., 1928 | Nov., 1928 | Feb., 1929 | May, 1929 | Average of all tests* |
|---|---|---|---|---|---|
| Number of cows milked | 80 | 65 | 52 | 69 | 67 |
| Gallons of milk cooled per day | 213 | 120 | 100 | 185 | 155 |
| Gallons of milk stored per day | 103 | 60 | 50 | 91 | 76 |
| Number of hours compressor was run per day | 19.3 | 12.2 | 6.6 | 20.0 | 14.5 |
| Kw.-hr. used by compressor motor per day | 21.5 | 15.4 | 5.8 | 21.1 | 16.0 |
| Kw -hr. used by brine pump motor per day | 1.0 | 1.0 | .8 | 1.6 | 1.1 |
| Total kw.-hr. used per day | 22.5 | 16.4 | 6.6 | 22.7 | 17.1 |
| Average brine temperature, degrees Fahr | 22 | 20 | 28 | 25 | 24 |
| Degrees rise in brine temperature during cooling, degrees Fahr | 4 | 3 | 4 | 6 | 4 |
| Average storage box temperature, degrees Fahr | 43 | 40 | 34 | 43 | 40 |
| Average milk room temperature, degrees Fahr | 71 | 58 | 47 | 65 | 60 |
| Milk temperature before cooling, degrees Fahr | 96 | 92 | 91 | 94 | 93 |
| Milk temperature after water cooled, degrees Fahr | 65 | 63 | 57 | 64 | 62 |
| Milk temperature after brine cooled, degrees Fahr | 43 | 35 | 34 | 38 | 38 |
| Rate of flow of cooling water, g.p.m. | 6.0 | 4.4 | 4.0 | 5.0 | 4.9 |
| Rate of flow of milk over aerator, g.p.h. | 35 | 22 | 21 | 26 | 26 |
| Temperature of cooling water, degrees Fahr | 63 | 60 | 56 | 62 | 60 |

* Nearest whole number.

## TABLE 10

### Operating Characteristics on Dairy No. 5

Milk cooling plant installed August, 1927.
Ice-melting effect per 24 hours of ice machine: one ton.
Condenser cooling medium: water.
Refrigerant: ammonia.
Horsepower of motor: 2 horsepower.
Type of storage box: "walk-in," made on the farm.
Inside dimensions of storage box: $5' \times 6' \times 6\frac{1}{2}'$.
Insulation of storage box: 6 inches granulated cork.
Gallons of brine: none.
Size and type of aerator: 30" wide, 20" deep, two-way direct expansion.
Cost of complete plant: $1450.

*Remarks:* Between the winter and spring tests, the storage box was increased in size to $5' \times 12' \times 6'$ with $2\frac{1}{2}' \times 5' \times 6'$ partitioned off for food-stuffs, and a 140-gallon brine tank was placed on the floor in one corner of the storage box. It was used only to keep a uniform box temperature and to make ice and not to cool the milk. The ice machine was moved and recharged with 50 pounds of ammonia. During the spring test about 50 pounds of ice was made per day. Three men did all the milking by hand. The evening's milk was stored overnight and both milkings shipped by truck a distance of 10 miles each morning. During the winter test the ice machine was used for cooling the milk only in the evening.

| | Aug., 1928 | Oct., 1928 | Feb., 1929 | May, 1929 | Average of all tests* |
|---|---|---|---|---|---|
| Number of cows milked | 72 | 72 | 72 | 80 | 74 |
| Gallons of milk cooled per day | 225 | 189 | 77† | 235 | 182 |
| Gallons of milk stored per day | 112 | 97 | 77 | 123 | 102 |
| Hours compressor was run per day | 7.4 | 6.3 | 3.1 | 9.7 | 6.6 |
| Kw.-hr. used by compressor motor per day | 7.1 | 6.5 | 2.8 | 10.6 | 6.8 |
| Kw.-hr. used by brine pump motor per day | 0 | 0 | 0 | 0 | 0 |
| Total kw.-hr. used per day | 7.1 | 6.5 | 2.8 | 10.6 | 6.8 |
| Average storage box temperature, degrees Fahr. | 50 | 45 | 42 | 39 | 44 |
| Average milk room temperature, degrees Fahr. | 77 | 60 | 49 | 67 | 63 |
| Milk temperature before cooling, degrees Fahr. | 95 | 94 | 90 | 94 | 93 |
| Milk temperature after water cooled, degrees Fahr. | 65 | 62 | 59 | 65 | 63 |
| Milk temperature after totally cooled, degrees Fahr. | 52 | 44 | 41 | 44 | 45 |
| Rate of flow of cooling water, g.p.m. | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Rate of flow of milk on aerator, g.p.h. | 36 | 36 | 31 | 41 | 36 |
| Temperature of cooling water, degrees Fahr. | 64 | 61 | 57 | 61 | 61 |

* Nearest whole number.
† Evening's milking only cooled by ice machine.

## TABLE 11

### OPERATING CHARACTERISTICS ON DAIRY NO. 6

Milk cooling plant installed July, 1927.
Ice-melting effect per 24 hours of ice machine: 1.5 tons.
Condenser cooling medium: water.
Refrigerant: ammonia.
Horsepower of motor: 3 horsepower.
Type of storage box: "walk-in," made on farm.
Inside dimensions of storage box: $6' \times 11' \times 7'$.
Insulation of storage box: 4 inches of rice hulls.
Gallons of brine: 350 gallons.
Kind of brine: common salt.
Location of brine tank: on floor at one end of box.
Size and type of brine pump: ¾ inch centrifugal.
Horsepower of brine pump motor: ½ horsepower.
Size and type of aerator: 36" wide, 15" deep, two-way.
Cost of complete plant: $1500.

*Remarks:* The plant is manually controlled. A space $4' \times 6' \times 7'$ was partitioned off at one end of the storage box to store food-stuffs. The morning's milk was stored 24 hours, and the evening's milk 12 hours. Both milkings were hauled a distance of 10 miles by truck in the morning to the distributing plant. Three men did the milking by hand. Except during the winter test, about 50 pounds of ice was made a day. The compressor was charged with ammonia twice during the year. The compressor motor burned out once in consequence of the power being turned off and on.

| | Aug., 1928 | Oct., 1928 | Feb., 1929 | May, 1929 | Average of all tests* |
|---|---|---|---|---|---|
| Number of cows milked | 80 | 75 | 55 | 95 | 76 |
| Gallons of milk cooled per day | 214 | 233 | 102 | 238 | 197 |
| Gallons of milk stored per day | 214 | 233 | 102 | 238 | 197 |
| Hours compressor was run per day | 9.9 | 7.9 | 4.2 | 8.8 | 7.7 |
| Kw.-hr. used by compressor motor per day | 22.9 | 15.8 | 8.1 | 17† | 16.0 |
| Kw.-hr. used by brine pump motor per day | 2.0 | 2.0 | 1.0 | 2.5 | 1.9 |
| Total kw.-hr. used per day | 24.9 | 17.8 | 9.1 | 19.5 | 17.9 |
| Average brine temperature, degrees Fahr | 25 | 20 | 18 | 20 | 21 |
| Degrees rise in brine temperature during cooling, degrees Fahr | 5 | 2 | 1 | 3 | 3 |
| Average storage box temperature, degrees Fahr | 40 | 39 | 32 | 35 | 36 |
| Average milk room temperature, degrees Fahr | 77 | 60 | 47 | 67† | 63 |
| Milk temperature before cooling, degrees Fahr | 93 | 92 | 84 | 92 | 90 |
| Milk temperature after water cooled, degrees Fahr | 73 | 72 | 65 | 73 | 71 |
| Milk temperature after brine cooled, degrees Fahr | 47 | 46 | 43 | 47 | 46 |
| Rate of flow of cooling water, g.p.m | 2.0 | 2.5 | 1.0 | 1.0 | 1.4 |
| Rate of flow of milk over aerator, g.p.h | 53 | 53 | 53 | 44 | 50 |
| Temperature of cooling water, degrees Fahr | 63 | 61 | 52 | 62 | 60 |

* Nearest whole number.
† Estimated.

TABLE 12

Operating Characteristics on Dairies 7, 8, and 9 on Which Only a Summer Observation Was Made: Tests, July, 1929

| | Dairy No. 7 | Dairy No. 8 | Dairy No. 9 |
|---|---|---|---|
| Milk cooling plant installed | March, 1929 | | May, 1929. |
| Ice-melting effect per 24 hours of ice machine | 1000 pounds | 500 pounds | 500 pounds. |
| Condenser cooling medium | Water | Water | Water. |
| Refrigerant | $SO_2$ | $SO_2$ | $SO_2$. |
| Horsepower of motor | 1 horsepower | ½ horsepower | ½ horsepower. |
| Type of storage box | None | None | "Walk-in." |
| Inside dimensions of storage box | | | 5′ x 5′ x 8′ |
| Gallons of brine | 200 | 160 | 120. |
| Insulation of brine tank or storage box | 3″ sheet cork | 4″ shavings | 2″ celotex. |
| Kind of brine | Calcium chloride | Calcium chloride | Calcium chloride. |
| Location of brine tank | Special insulated box | Special insulated box | Upper half of storage box. |
| Size and type of brine pump motor | ½″ centrifugal | ½″ centrifugal | ½″ centrifugal. |
| Horsepower of brine pump motor | ¼ horsepower | ¼ horsepower | ¼ horsepower. |
| Size of aerator | 30″ x 24″ | 18″ x 24″ | 24″ x 18″. |
| Cost of complete plant | $900 | | |

| | Dairy No. 7 | Dairy No. 8 | Dairy No. 9 |
|---|---|---|---|
| Number of cows milked | 95 | 55 | 18 |
| Gallons of milk cooled per day | 318 | 124 | 45 |
| Gallons of milk stored per day | 0 | 0 | 22 |
| Number of hours compressor was run per day | 14.5 | 17.5 | 16.1 |
| Kw.-hr..used by compressor motor | 16.0 | 10.7 | 9.3 |
| Kw.-hr. used by brine pump motor | 1.3 | 1.0 | .5 |
| Total kw -hr. used per day | 17.3 | 11.7 | 9.8 |
| Average brine temperature, degrees Fahr | 29 | 20 | 22 |
| Degrees rise in brine temperature during cooling, degrees Fahr | 16 | 15 | 8 |
| Average storage box temperatures, degrees Fahr | | | 46 |
| Average milk room temperature, degrees Fahr | 79 | 77 | 77 |
| Milk temperature before cooling, degrees Fahr | 96 | 96 | 93 |
| Milk temperature after water cooled, degrees Fahr | 73 | 73 | 75 |
| Milk temperature after brine cooled, degrees Fahr | 47 | 41 | 43 |
| Rate of flow of cooling water, g.p.m | 4.0 | 3.2 | 2.5 |
| Rate of flow of milk over aerator, g.p.h | 83 | 25 | 22 |
| Temperature of cooling water, degrees Fahr | 68 | 68 | 67 |

## SUMMARY AND RECOMMENDATIONS[7]

| | |
|---|---|
| Specific heat of milk | .93 |
| Heat removed in cooling one gallon of milk 1 deg. Fahr | 8.00 B.t.u. |
| Temperature of milk as it is started over aerator in warm weather | 93°–98° Fahr. |
| Temperature of milk as it is started over aerator in cold weather | 85°–90° Fahr. |
| Diameter of a 10-gallon milk can | 13½ inches |
| Height of a 10-gallon milk can | 24 inches |
| Weight of a 10-gallon milk can | 18–23 pounds |
| Size of a 12-quart-bottle crate | 14 x 18 x 11 inches |
| Weight of a 12-quart-bottle crate | 12 to 15 pounds |
| Weight of a quart bottle (empty) | 1½ to 2 pounds |

1. Milk is cooled to retard bacterial increase and preserve quality.

2. Cooling milk on the dairy farm is required by state and city regulations for the production of market milk.

3. Mechanical refrigerating machines are an efficient and economical means of accomplishing this cooling, if equipment of the proper size and type is used.

4. Two types of milk cooling plants are in use, the 'wet' and the 'dry.' The 'dry' type, used almost entirely in California, may be either a brine or direct expansion system.

5. Milk, after being drawn from the cow, is usually handled on the farm in one of three ways: cooled and stored in 10-gallon cans and shipped to the distributing plant once a day; cooled and stored in bottles and delivered once a day; or cooled and shipped to the distributing plant after each milking.

6. The electric power consumption for the operation of a farm milk cooling plant depends upon the method of handling the milk, the time of the year, the type of plant or system, and the construction and operation of the plant.

*a.* When the milk is cooled and stored in 10-gallon cans, the brine system being used, about .12 kw-hr. is consumed per gallon of milk.

*b.* When the milk is cooled and stored in bottles the brine system being used, .17 kw-hr. is consumed per gallon of milk.

*c.* When the milk is cooled and not stored, the brine system being used, about .09 kw-hr. is consumed per gallon of milk.

*d.* When cooled and stored or not stored, the direct expansion system being used, about .05 kw-hr. is consumed per gallon of milk.

[7] For convenience in calculating, a table of weights, temperatures and measurements is given herewith:

7. Estimating electric power at 2 cents per kilowatt-hour, depreciation at 10 per cent, interest at 7 per cent, and upkeep at 3 per cent per annum, a milk-cooling plant, will cost from ½ cent to 1 cent per gallon cooled, depending on the size and type of plant and the method of handling the milk.

8. Recommendations for the selection and operation of a 'dry' type of farm milk cooling plant:

*a.* The profit that is to be gained by the use of such a plant should be determined and the dairy inspector in charge consulted on the requirements to be met for producing the grade of milk desired.

*b.* In purchasing the equipment one should obtain as much information as possible on the different makes and types and make a decision on the relative merits, the size of units, the price, the reputation of the manufacturer and dealer, and the service obtainable.

*c.* Efficiency and length of life are as important as initial cost. Poor equipment usually means poor efficiency, and although the initial cost may be lower, the saving will be offset by increased operating cost, depreciation, and upkeep.

*d.* Future increase in quantity of milk to be cooled should be considered, as it is sometimes more economical to take care of future needs by installing the original plant larger than necessary at the time. Selection of proper size of refrigerating machine is very essential. Recommended sizes are given in table 13.

TABLE 13

Size of Compressor for Handling Different Quantities of Milk

| Size of compressor* | | Horsepower of compressor motor | | Gallons of milk cooled and stored per day using brine system | Gallons of milk per day when cooled only, using brine system | Gallons of milk per day when cooled and stored, or cooled only, using direct expansion system |
|---|---|---|---|---|---|---|
| In pounds ice-melting effect per 24 hours | In tons of ice-melting effect per 24 hours | With water-cooled condenser | With air-cooled condenser | | | |
| 500 | ¼ | ½ | ¾ | 50-100 | 75-125 | 50- 75 |
| 750 | ⅜ | ¾ | 1 | 100-150 | 125-200 | 75-100 |
| 1000 | ½ | 1 | 1½ | 150-200 | 200-250 | 100-150 |
| 1500 | ¾ | 1½ | 2 | 200-275 | 250-325 | 150-200 |
| 2000 | 1 | 2 | 3 | 275-350 | 325-400 | 200-250 |
| 3000 | 1½ | 3 | ..... | 350-400 | 400-450 | 250-300 |

* If it is desired to make ice, the capacity of the compressor should be increased by approximately twice the quantity of ice it is desired to make per day.

*f.* If a storage box is needed, a floor space of $15 \times 15$ inches should be allowed for each 10-gallon container that is to be stored. Where the milk is stored in quart bottle cases, a space $16 \times 20 \times 12$ inches should be allowed for each case.

*g.* The equivalent of 3 to 4 inches of sheet cork should be used for insulation of the brine tank or storage box.

*h.* If the brine system is used the tank should contain from 1.5 to 2 gallons of brine for each gallon of milk cooled per day.

*i.* A ½-inch centrifugal brine pump driven by a ¼-horsepower motor is sufficient for circulating the brine where less than 200 gallons per day are cooled. A ¾-inch centrifugal pump driven by a ¼-horsepower motor is sufficient where 200 to 400 gallons of milk are cooled per day.

*j.* The aerator should be of the two-way type, with water passing through the upper half and brine through the lower half. Approximately 6 inches of horizontal length should be allowed for each 10 gallons of milk cooled per hour.

*k.* The different units of the plant should be arranged so as to require a minimum of labor for cleaning, operating, and repairing.

*l.* The dairyman should learn the various adjustments necessary for correct and efficient operation of the plant. It is good practice to keep a thermometer available and check the temperatures occasionally.

*m.* The milk should be cooled to about 10° Fahr. below the temperature at which it is to be delivered to the distributing plant. About 40° Fahr. is the usual desired temperature of cooling over the aerator.

*n.* The storage box temperature should be kept a few degrees lower than the temperature to which the milk is cooled.

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